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Quick-change regional aircraft

QCRA

QC AIRCRAFT

Contents: BUDGET

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1 Introduction

This document aims to estimate the costs of the Quick-Change Regional Aircraft, which will include the raw materials required for its assembly as well as its associated manufacturing cost. Moreover, it is important to highlight that no operating costs are considered in the budget. The budget associated to the development of the project charter has been included as an operational expense in the *Economics Attachment, section 5.2.1*. This budget only refers to the raw materials and to the manufacturing cost that will be used when analysing the feasibility of the project, see *Economics Attachment, section 5.3.4*.

In order to estimate the budget, two different methods are considered: the Breakdown method and William's method. This will allow us to compare the results obtained through both methods in order to double check if the right procedures are being followed.

The first method consists in an organisation of the budget in different sections containing the components required by each type of resource, thus computing the sub-totals and, finally, providing a total project cost. As a preliminary study is being conducted, contingencies will be considered as some components may be missing. Each section will estimate a percentage value for contingencies.

The second method is based on an analogy study of a similar project and it will serve as a reference to validate the first method. This comparison will be carried out with the Bombardier Q400 and a characteristic parameter from each plane.

Although the currency used in the Feasibility Study is the euro, the budget is calculated in dollars as most of the references and components have been found in dollars. At the end of this document, a conversion of 1,20 EUR/USD has been applied to obtain the budget in euros.

2 Manufacturing costs

2.1 Breakdown Method

For this section it is shown a classification of the main components, its cost per unit and final total cost by type of resource, which are divided into 4 groups:

- Structural elements
- Systems and Instruments
- Aerodynamic elements
- Propulsion elements

To do so, it has been used data extracted from [1], which is a list of all the items used for the assembly of the ATR-42. Due to the huge similarities between the ATR-42 and the QC Regional Aircraft, the vast majority of the systems and also the aerodynamic elements on board will be extracted by analogy from the reference mentioned above. On the other side, the price of the propulsion plant, specially the engine and the propeller, have been obtained from references [2] and [3], respectively. Finally, the price for other items that have been designed by the team, such as the material of the skin, ribs, spars, and other structural and aerodynamic elements, have been calculated in the *Economics Attachment section 5.2.2*.

2.1.1 Units

Table 1: Units of the structural components.

1.- Structural elements		
ID	**Item**	**Units**
1.1	Cargo Door	1
1.2	Passenger Door	1
1.3	Emergency Exit Door	2
1.4	Interiors for passengers	50
1.5	Attendant Seat	1
1.6	Titanium Spars Wings	299.78 kg
1.7	Aluminium Spars Wings	224.80 kg
1.8	Ribs Wings	519.85 kg
1.9	Wing Skins	1,348.80 kg
1.10	Fuselage Material	2,162.00 kg
1.11	Empennage Material	545.00 kg
1.12	Rail system	1
1.13	Windows glass	28

Table 1: Units of the structural components.

1.- Structural elements		
ID	**Item**	**Units**
1.14	Landing gear	1

Table 2: Units of systems components.

2.- Systems and instruments		
ID	**Item**	**Units**
2.1 Instrumentation and avionics		
2.1.1	Traffic collision avoidance system (TCAS)	1
2.1.2	Control TCAS	1
2.1.3	Indicator-Standby Horizon	1
2.1.4	Multipurpose Control Display Unit	1
2.1.5	Symbol Generator Unit	2
2.1.6	Electronic System Unit	1
2.1.7	Electronics Power Control Indicator	1
2.1.8	Display Unit-EFIS	4
2.1.9	Air Data Computer	2
2.1.10	Vertical Speed Indicator	4
2.1.11	Enhanced Ground Proximity Warning Computer	1
2.1.12	Turn indicator	2
2.1.13	Transceiver-VHF	2
2.1.14	Control Unit-VHF	2
2.1.15	Transponder ATC Mode S	2
2.1.16	Total Temperature Sensor	1
2.1.17	Clock	1
2.1.18	Radio Magnetic Indicator	2
2.1.19	Airspeed Indicator	2
2.1.20	Transceiver-Radio Altimeter	1
2.1.21	Indicator Altitude	2
2.1.22	Cockpit Voice Recorder	1
2.1.23	Flight Data Recorder	1
2.1.24	Attitude and Heading Reference Unit (AHRU)	2
2.1.25	Crew Alerting Computer	1
2.1.26	Control Unit-VOR/ILS/DME	2

Table 2: Units of systems components.

2.- Systems and instruments		
ID	**Item**	**Units**
2.1.27	Weather Radar Receiver/Transceiver	1
2.1.28	Weather Radar Controller	1
2.1.29	Flight Guidance Computer	1
2.2 Hydraulic systems		
2.2.1	Hydraulic Anti-Skid Valve Manifold	1
2.2.2	Hydraulic Pump	1
2.2.3	Hydraulic Reservoir	1
2.2.4	Brake	4
2.2.5	Cylinders and actuators	1
2.2.6	Damper	1
2.3 Electrical System		
2.3.1	RG-380E/44 battery	1
2.3.2	RG-42 battery	1
2.3.3	Battery Protection Unit	2
2.3.4	Starter generator DC	2
2.3.5	DC GCU	2
2.3.6	Inverter	2
2.3.7	TRU	2
2.3.8	AC Generator	2
2.3.9	AC GCU	2
2.3.10	Control Unit-Propeller	1
2.3.11	Engine Electronic Control	1
2.3.12	Fuel Pump	1

Table 3: Units of the aerodynamic components.

3.- Aerodynamic elements		
ID	**Item**	**Units**
3.1	Angle of attack sensors	2
3.2	Inboard Flaps	2
3.3	Outboard Flaps	2
3.4	Elevator	2
3.5	Valve-De Icing Dual Distributor	4

Table 3: Units of the aerodynamic components.

3.- Aerodynamic elements		
ID	**Item**	**Units**
3.6	Fairing Pannels	1

Table 4: Units of the propulsion components.

4.- Propulsion elements		
ID	**Item**	**Units**
4.1	PW127N Engine	2
4.2	Hamilton Standard 568 Propeller	2
4.3	Engine mount	2
4.4	Propeller brake	2
4.5	Prop oil transfer tube	2
4.6	Exhaust & recirculation fans	1
4.7	Air intake	2
4.8	Engine Truss- FWD	2
4.9	Spinner	2
4.10	Fan	1
4.11	Pump-Propeller Feathering	1
4.12	Control Unit-Propeller	1

2.1.2 Costs per unit

Table 5: Cost per unit of the structural components.

1.- Structural elements		
ID	**Item**	**Cost per Unit ($)**
1.1	Cargo Door	431,418.92
1.2	Passenger Door	309,449.43
1.3	Emergency Exit Door	96,950.06
1.4	Interiors for passengers	1700.00
1.5	Attendant Seat	26,883.92
1.6	Titanium Spars Wings	$ 20.00/kg
1.7	Aluminium Spars Wings	$ 4.80/kg
1.8	Ribs Wings	$ 4.80/kg
1.9	Wing Skins	$ 4.80/kg
1.10	Fuselage Material	$ 4.80/kg
1.11	Empennage Material	$ 4.80/kg
1.12	Rail system	2,000.00
1.13	Windows glass	400.00
1.14	Landing gear	616,438.00

Table 6: Cost per unit of systems components.

2.- Systems and instruments		
ID	**Item**	**Cost per Unit ($)**
2.1 Instrumentation and avionics		
2.1.1	Traffic collision avoidance system (TCAS)	179,769.64
2.1.2	Control TCAS	7,618.37
2.1.3	Indicator-Standby Horizon	14,075.48
2.1.4	Multipurpose Control Display Unit	101,190.21
2.1.5	Symbol Generator Unit	136,569.34
2.1.6	Electronic System Unit	7,159.16
2.1.7	Electronics Power Control Indicator	7,959.54
2.1.8	Display Unit-EFIS	44,513.63
2.1.9	Air Data Computer	101,591.44
2.1.10	Vertical Speed Indicator	30,694.71
2.1.11	Enhanced Ground Proximity Warning Computer	72,516.12

Table 6: Cost per unit of systems components.

2.- Systems and instruments		
ID	**Item**	**Cost per Unit ($)**
2.1.12	Turn indicator	12,911.50
2.1.13	Transceiver-VHF	16,365.04
2.1.14	Control Unit-VHF	4,903.21
2.1.15	Transponder ATC Mode S	40,626.35
2.1.16	Total Temperature Sensor	19,817.21
2.1.17	Clock	425.00
2.1.18	Radio Magnetic Indicator	12,636.76
2.1.19	Airspeed Indicator	13,473.88
2.1.20	Transceiver-Radio Altimeter	22,417.69
2.1.21	Indicator Altitude	17,436.52
2.1.22	Cockpit Voice Recorder	12,516.17
2.1.23	Flight Data Recorder	12,679.38
2.1.24	Attitude and Heading Reference Unit (AHRU)	147,945.04
2.1.25	Crew Alerting Computer	125,487.20
2.1.26	Control Unit-VOR/ILS/DME	4,529.81
2.1.27	Weather Radar Receiver/Transceiver	51,428.01
2.1.28	Weather Radar Controller	9,834.99
2.1.29	Flight Guidance Computer	61,402.60
2.2 Hydraulic systems		
2.2.1	Hydraulic Anti-Skid Valve Manifold	126,000.00
2.2.2	Hydraulic Pump	22,554.52
2.2.3	Hydraulic Reservoir	22,418.41
2.2.4	Brake	22,883.59
2.2.5	Cylinders and actuators	335,000.00
2.2.6	Damper	14.600,57
2.3 Electrical System		
2.3.1	RG-380E/44 battery	2,942.65
2.3.2	RG-42 battery	3,445.77
2.3.3	Battery Protection Unit	12,719.82
2.3.4	Starter generator DC	32,656.34
2.3.5	DC GCU	28,563.28
2.3.6	Inverter	20,000.00

Table 6: Cost per unit of systems components.

2.- Systems and instruments		
ID	**Item**	**Cost per Unit ($)**
2.3.7	TRU	10,000.00
2.3.8	AC Generator	53,529.69
2.3.9	AC GCU	26,070.67 4
2.3.10	Control Unit-Propeller	75,385.73
2.3.11	Engine Electronic Control	51,840.81
2.3.12	Fuel Pump	23,561.56

Table 7: Cost per unit of the aerodynamic components.

3.- Aerodynamic elements		
ID	**Item**	**Cost per Unit ($)**
3.1	Angle of attack sensors	15,157.50
3.2	Inboard Flaps	512,656.00
3.3	Outboard Flaps	480,149.30
3.4	Elevator	286,895.00
3.5	Valve-De Icing Dual Distributor	12,018.00
3.6	Fairing Pannels	822,389.39

Table 8: Cost per unit of the propulsion components.

4.- Propulsion elements		
ID	**Item**	**Cost per Unit ($)**
4.1	PW127N Engine	1,050,000.00
4.2	Hamilton Standard 568 Propeller	70,000.00
4.3	Engine mount	111,833.00
4.4	Propeller brake	69,416.00
4.5	Prop oil transfer tube	18,735.00
4.6	Exhaust & recirculation fans	34,444.30
4.7	Air intake	70,451.10
4.8	Engine Truss- FWD	194,444.44
4.9	Spinner	9.545,02
4.10	Fan	21,359.87
4.11	Pump-Propeller Feathering	8,551.14

Table 8: Cost per unit of the propulsion components.

4.- Propulsion elements		
ID	**Item**	**Cost per Unit ($)**
4.12	Control Unit-Propeller	75,385.73

2.1.3 Budget breakdown

Table 9: Total costs of the structural components.

1.- Structural elements				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
1.1	Cargo Door	1	431,418.92	431,418.92
1.2	Passenger Door	1	309,449.43	309,449.43
1.3	Emergency Exit Door	2	96,950.06	193,900.12
1.4	Interiors for passengers	50	1700	431,418.92
1.5	Attendant Seat	1	26,883.92	26,883.92
1.6	Titanium Spars Wings	299.78 kg	$ 20.00/kg	5,995.50
1.7	Aluminium Spars Wings	224.80 kg	$ 4.80/kg	1,079.04
1.8	Ribs Wings	519.85 kg	$ 4.80/kg	2,495.28
1.9	Wing Skins	1,348.80 kg	$ 4.80/kg	6,482.00
1.10	Fuselage Material	2,162.00 kg	$ 4.80/kg	10,377.6
1.11	Empennage Material	545.00 kg	$ 4.80/kg	2,616.00
1.12	Rail system	1	2,000.00	2,000.00
1.13	Windows glass	28	400.00	11,200.00
1.14	Landing gear	1	616,438.00	616,438.00

Table 10: Total costs of systems components.

2.- Systems and instruments				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
2.1 Instrumentation and avionics				
2.1.1	Traffic collision avoidance system (TCAS)	1	179,769.64	179,769.64
2.1.2	Control TCAS	1	7,618.37	7,618.37
2.1.3	Indicator-Standby Horizon	1	14,075.48	14,075.48
2.1.4	Multipurpose Control Display Unit	1	101,190.21	101,190.21
2.1.5	Symbol Generator Unit	2	136,569.34	273,138.68
2.1.6	Electronic System Unit	1	77,159.16	77,159.16
2.1.7	Electronics Power Control Indicator	1	7,959.54	7,959.54
2.1.8	Display Unit-EFIS	4	44,513.63	178,054.52
2.1.9	Air Data Computer	2	101,591.44	203,182.88
2.1.10	Vertical Speed Indicator	4	30,694.71	122,778.84
2.1.11	Enhanced Ground Proximity Warning Computer	1	72,516.12	72,516.12

Table 10: Total costs of systems components.

2.- Systems and instruments				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
2.1.12	Turn indicator	2	12,911.50	25,823.00
2.1.13	Transceiver-VHF	2	16,365.04	32,730.08
2.1.14	Control Unit-VHF	2	4,903.21	9,806.42
2.1.15	Transponder ATC Mode S	2	40,626.35	81,252.70
2.1.16	Total Temperature Sensor	1	19,817.21	19,817.21
2.1.17	Clock	1	425.00	425.00
2.1.18	Radio Magnetic Indicator	2	12,636.76	25,273.52
2.1.19	Airspeed Indicator	2	13,473.88	26,947.76
2.1.20	Transceiver-Radio Altimeter	1	22,417.69	22,417.69
2.1.21	Indicator Altitude	2	17,436.52	34,873.04
2.1.22	Cockpit Voice Recorder	1	12,516.17	12,516.17
2.1.23	Flight Data Recorder	1	12,679.38	12,679.38
2.1.24	Attitude and Heading Reference Unit (AHRU)	2	147,945.04	295,890.08
2.1.25	Crew Alerting Computer	1	125,487.20	125,487.20
2.1.26	Control Unit-VOR/ILS/DME	2	4,529.81	9,059.62
2.1.27	Weather Radar Receiver/Transceiver	1	51,428.01	51,428.01
2.1.28	Weather Radar Controller	1	9,834.99	9,834.99
2.1.29	Flight Guidance Computer	1	61,402.60	61,402.60
2.2 Hydraulic systems				
2.2.1	Hydraulic Anti-Skid Valve Manifold	1	126,000.00	126,000.00
2.2.2	Hydraulic Pump	1	22,554.52	22,554.52
2.2.3	Hydraulic Reservoir	1	22,418.41	22,418.41
2.2.4	Brake	4	22,883.59	91,534.36
2.2.5	Cylinders and actuators	1	335,000.00	335,000.00
2.2.6	Damper	1	14,600.57	14,600.57
2.3 Electrical System				
2.3.1	RG-380E/44 battery	1	2,942.65	2,942.65
2.3.2	RG-42 battery	1	3,445.77	3,445.77
2.3.3	Battery Protection Unit	2	12,719.82	25,439.64
2.3.4	Starter generator DC	2	32,656.34	65,312.68
2.3.5	DC GCU	2	28,563.28	57,126.56
2.3.6	Inverter	2	20,000.00	40,000.00

Table 10: Total costs of systems components.

2.- Systems and instruments				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
2.3.7	TRU	2	10,000.00	20,000.00
2.3.8	AC Generator	2	53,529.69	107,059.38
2.3.9	AC GCU	2	26,070.67	52,141.34
2.3.10	Control Unit-Propeller	1	75,385.73	75,385.73
2.3.11	Engine Electronic Control	1	51,840.81	51,840.81
2.3.12	Fuel Pump	1	23,561.56	23,561.56

Table 11: Total costs of the aerodynamic components.

3.- Aerodynamics elements				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
3.1	Angle of attack sensors	2	15,157.50	30,315.00
3.2	Inboard Flaps	2	512,656.00	1,025,312.00
3.3	Outboard Flaps	2	480,149.30	960,298.60
3.4	Elevator	2	286,895.00	573,790.00
3.5	Valve-De Icing Dual Distributor	4	12,018.00	48,072.00
3.6	Fairing Pannels	1	822,389.39	822,389.39

Table 12: Total costs of the propulsion components.

4.- Propulsion elements				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
4.1	PW127N Engine	2	1,050,000.00	2,100,000.00
4.2	Hamilton Standard 568 Propeller	2	70,000.00	140,000.00
4.3	Engine mount	2	111,833.00	223,666.00
4.4	Propeller brake	2	69,416.00	138,832.00
4.5	Prop oil transfer tube	2	18,735.00	37,470.00
4.6	Exhaust & recirculation fans	1	34,444.30	34,444.30
4.7	Air intake	2	70,451.10	140,902.20
4.8	Engine Truss- FWD	2	194,444.44	388,888.88
4.9	Spinner	2	9.545,02	19,090.04
4.10	Fan	1	21,359.87	21,359.87
4.11	Pump-Propeller Feathering	1	8,551.14	8,551.14

Table 12: Total costs of the propulsion components.

4.- Propulsion elements				
ID	**Item**	**Units**	**Cost per Unit ($)**	**Total Cost ($)**
4.12	Control Unit-Propeller	1	75,385.73	75,385.73

2.1.4 Total Cost

In the following table the total cost of the aircraft is computed by aggregating all the costs from all of the chapters. Apart from the cost breakdown exposed in the previous section, the associated contingencies have also been accounted in the final budget. On the other side, the manufacturing labour has been added to the total cost, which includes the tooling, quality tests and flight tests costs. These have been computed in *Business Attachment, section 2.2*.

Table 13: Total cost of the aircraft.

Total cost	
Cost type	**Cost ($)**
Structural elements	
Raw material	2,051,754.73
Contingencies (5%)	102,587.74
Systems and instrumentation	
Raw material	3,231,471,89
Contingencies (15%)	484,720.78
Aerodynamic elements	
Raw material	3,460,176.99
Contingencies (15%)	519,026.55
Propulsion elements	
Raw material	3,328,590.16
Contingencies (10%)	332,859.02
Manufacturing labour	
Tooling	255,026.908
Quality tests	37,176.819
Flight tests	29,085.553
TOTAL COST: $16,724,079	

Finally, this Breakdown method concludes that the estimation for the budget required to produce and assemble an aircraft will be of $16,724,079, which is equivalent to **13,936,725 €**

2.2 Budget estimation using William's method

The aim of this section is to verify if the budget obtained in the previous chapter is realistic. In order to do this, the William's method is used to estimate the budget and compare it with the one obtained previously. This method states the following:

$$C_{QC} = C_A \left[\frac{T_{QC}}{T_A}\right]^n \tag{1}$$

Where C_{QC} and C_A are the costs of the QC Aircraft and of the reference aircraft respectively. T_{QC} and T_A are the characteristic parameters of both planes and, in this case, the number of passengers has been chosen. The cost rate n is estimated based on previous projects.

For this comparison, it has been chosen a similar turboprop aircraft, the Bombardier Q400, which has a capacity of 90 passengers.

Regarding the cost rate n, the coefficient is obtained by comparison between the price of the ATR 42 (a very similar aircraft) and the cost of the Bombardier Q400.

The ATR 42 was priced at $19,5 M in 2008. Using an inflation calculator, this price can be extrapolated to $23,5 M in 2020.

Table 14: Main parameters used in William's Method.

QC Aircraft		Bombardier Q400	
CQC	-	CA	32.2 M
TQC	50	TA	90

The n parameter is estimated at $n = 0.73$. It is the coefficient between the price of the ATR 42 ($23,5 M) and the cost of the Bombardier Q400 ($32,2 M).

The final cost estimation using the parameters in Table 14 is:

$$C_{QC} = 32,2\left[\frac{50}{90}\right]^{0,73} = \$20,96M \tag{2}$$

Changing the currency to euros, the sale price ends up being 17,65 M €.

The price obtained refers to the sale price, which differs from the raw material costs. To obtain the budget estimation, the gross margin of the ATR 42 has been taken into consideration. As a new ATR 42 is priced at $19,5 M and the cost of its parts is around $14,2 M, this implies a gross margin of 27%.

Extrapolating this gross margin for our particular case, the estimation for the cost of the parts of the QC Aircraft should be of around **12,8 M €**.

3 Budget

Comparing the value of the budget calculated using the breakdown method in *section 2.1* (13,93M €) and the estimation obtained in *section 2.2* (12,8M €), a divergence of 8,1% appears. It is absolutely negligible having in mind that in preliminary studies errors of up to 30% can be acceptable.

This way it has been concluded that the results obtained in *section 2.1* will be the final budget of the company, as the method used is much more accurate and precise.

The final budget for the QC aircraft is:

13,936,725 €

References

[1] bcnaviation. (2020). *Atr 42 generic parts list*. http://www.bcnaviation.com/images/ATR42-300%20Part%20Out%20Parts%20List-%20Generic.pdf (accessed: 28-10-2020)

[2] Aircraft Commerce. (2017). *Aircraft trading and the aftermarket*. https://www.ajw-group.com/storage/downloads/1485794895_the_used_market_for_regional__narrowbody_engines_aircraft_commerce.pdf (accessed: 23-10-2020)

[3] Aerobay. (2017). *568f propeller blade*. https://www.aero-bay.com/p/R815505-6/66463 (accessed: 23-10-2020)